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13. ABSTRACT (*Maximum 200 words*)

This document describes the equipment purchased under the Defense University Research Instrumentation Program awarded in 1997 to Nancy J. Cooke of the Psychology Department of New Mexico State University. The equipment is housed in the CERTT (Cognitive Research on Team Tasks) Laboratory of the Psychology Department. This laboratory is dedicated to research on team cognition and the development and evaluation of measures to support this research. The equipment consists of four interconnected participant workstations and an experimenter workstation, as well as a head tracker and newtork connections. Each workstation contains two computers and monitors, a video monitor, a communications module, and a video camera. Together, this equipment and associated software provide a platform for a variety of synthetic team tasks and support experimental control, data collection, and data analyses functions. The first synthetic task to be developed using this platform captures the cognitive requirements of a UAV (unmanned air vehicle) task.

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Facility for Cognitive Engineering Research on Team Tasks

Final Technical Report

CERTT Laboratory

Cognitive Engineering Research on Team Tasks

Department of Psychology
New Mexico State University
Las Cruces, New Mexico

Dr. Nancy Cooke - Laboratory Director

31 March 1998

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I. Introduction

This document describes the equipment purchased under the Defense University Research Instrumentation Program awarded in 1997 to Nancy J. Cooke of the Psychology Department of New Mexico State University. The equipment is housed in a facility called the CERTT Lab (Cognitive Engineering Research on Team Tasks) which is located in Room 265 of Science Hall at New Mexico State University. The lab consists of four NT-based participant workstations and an NT experimenter control workstation. The hardware is configured to support a variety of synthetic task environments, experimental requirements, and data collection and analyses modules. The initial software design focuses on a synthetic task that preserves many of the cognitive features of UAV (unmanned air vehicle) operation, in addition to modules for experimental control and data collection and analyses. Software development is ongoing with iterative testing and design cycles guiding the implementation of initial software design plans.

The purpose of the CERTT lab is to create a flexible research environment for the study of team cognition. In particular, measures of knowledge at the team level will be developed and evaluated in this setting. Functionality requirements for the lab were determined through a needs analysis of projected laboratory users including researchers in NMSU's Psychology Department, Armstrong Lab, and the Naval Air Warfare Center-Training Systems Division. This analysis indicated that while high fidelity simulations of the UAV task (and other team tasks) existed (e.g., at Williams AFB) what was still needed was a researcher-friendly facility that embodied a low-fidelity synthetic task that would permit various forms of experimental control, measurement, and a broad spectrum of participants

Therefore the workstations and software in the CERTT lab permit the simulation of a variety of complex team tasks. However, a major emphasis is placed on the functions required by experimenters to conduct research in such a setting, such as the ability to alter task parameters and record data from a variety of sources. The CERTT Lab is also

described in a newspaper clip from the local Las Cruces Sun News (August, 1997) reproduced in Figure 1.

NMSU study examines teamwork

By Dan Trujillo
NMSU

How can military pilots work more effectively with others as a team?

Questions like that should be answered once New Mexico State University's psychology department begins using its Cognitive Engineering Research on Team Tasks facility. The lab is being built at NMSU. Once completed, the lab will include specialized computer equipment and software for research to quantitatively assess variables affecting human performance.

EYE ON RESEARCH

Support for the equipment is being provided with a $256,104 U.S. Department of Defense University Research Instrumentation Program grant, which is being administered through the Air Force Office of Scientific Research.

NMSU associate psychology professor Nancy Cooke said the CERTT facility will be able to test a four-person team by using four interconnected computer work stations and a file server that will run software programs that simulate real tasks faced by teams.

Various scenarios can be created by changing the task's complexity, equipment faults and weather.

"This system is something like a high-performance, four-person video game," Cooke said. "But with this system we will be able to measure team performance and team knowledge, and how it affects performance.

"The facility, which records various behavioral and cognitive measures, will test team members on their awareness of the situation, shared mental models, communication and the relation of these factors to the team's performance.

"We want to know if team members have complementary knowledge of a given scenario, or conflicting knowledge, and how this shared knowledge relates to team performance," Cooke said.

Cooke said the goal of the research is to develop methods to measure team cognition and performance -- something critical to military team tasks.

Cooke said the Air Force and the U.S. Navy are interested in the CERTT results. In addition, the Naval Air Warfare Center in Orlando, White Sands Missile Range and possibly the Federal Aviation Administration may want to use the facility for testing teams.

Cooke said the software for the facility will be built in modules, so researchers can change CERTT scenarios to perform different functions. Eventually, CERTT will be able to track eye movements and keep a record of each participant through audio and visual analysis.

Final results of the testing are expected to be put to practical use in designing team training programs and equipment to facilitate team performance.

DURIP supports the purchase of state-of-the-art equipment that augments current university capabilities or develops new university capabilities to perform cutting-edge defense research. DURIP meets a critical need by enabling Department of Defense-supported university researchers to purchase scientific equipment that costs more than $50,000. The researchers normally have difficulty purchasing instruments that cost that much under their research grants and contracts.

Upcoming columns in NMSU offerings will highlight other research projects.

NMSU photo by Michael Kemas

Nancy Cooke, New Mexico State University associate psychology professor, looks on while psychology students Cathilia Flores and Valery Barton use the CERTT prototype.

Figure 1. Press release on the CERTT Lab, August, 1997.

The remainder of this document describes the CERTT laboratory from three perspectives:

- laboratory layout,
- workstation design, and
- software design.

II. Laboratory Layout

The following diagrams represent the layout of the equipment and signage within the CERTT Lab. The lab space includes one large room and three smaller rooms to the side, totaling approximately 600 square feet. The four participant workstations are currently arranged as indicated in Option A. These are single-participant workstations and the height of each workstation restricts participants' views of each other. Portable partitions can be easily installed if necessary to provide additional participant isolation. This feature, combined with the use of headsets for communication allows for task scenarios in which team members interact from isolated locations. However, arranging the workstations as shown in Option B allows for scenarios in which pairs of team members are co-located.

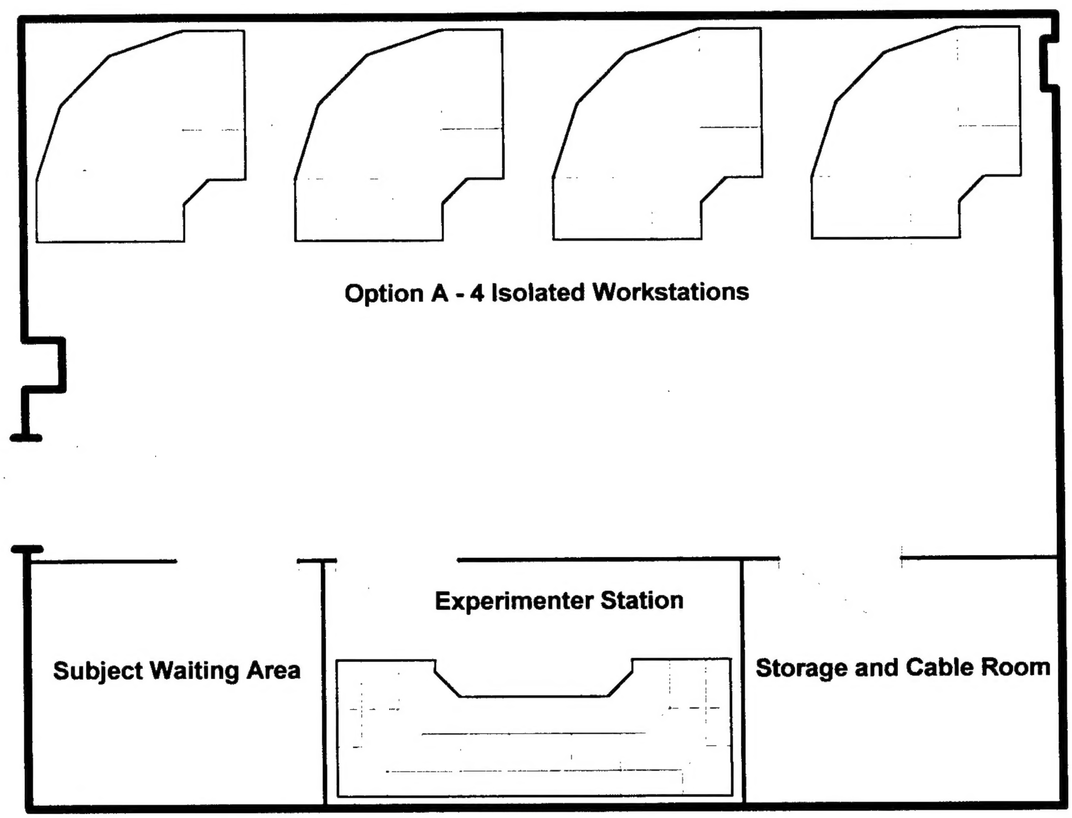


Figure 2. CERTT Floor Plan - Console Layout Option A *(drawn to scale).*

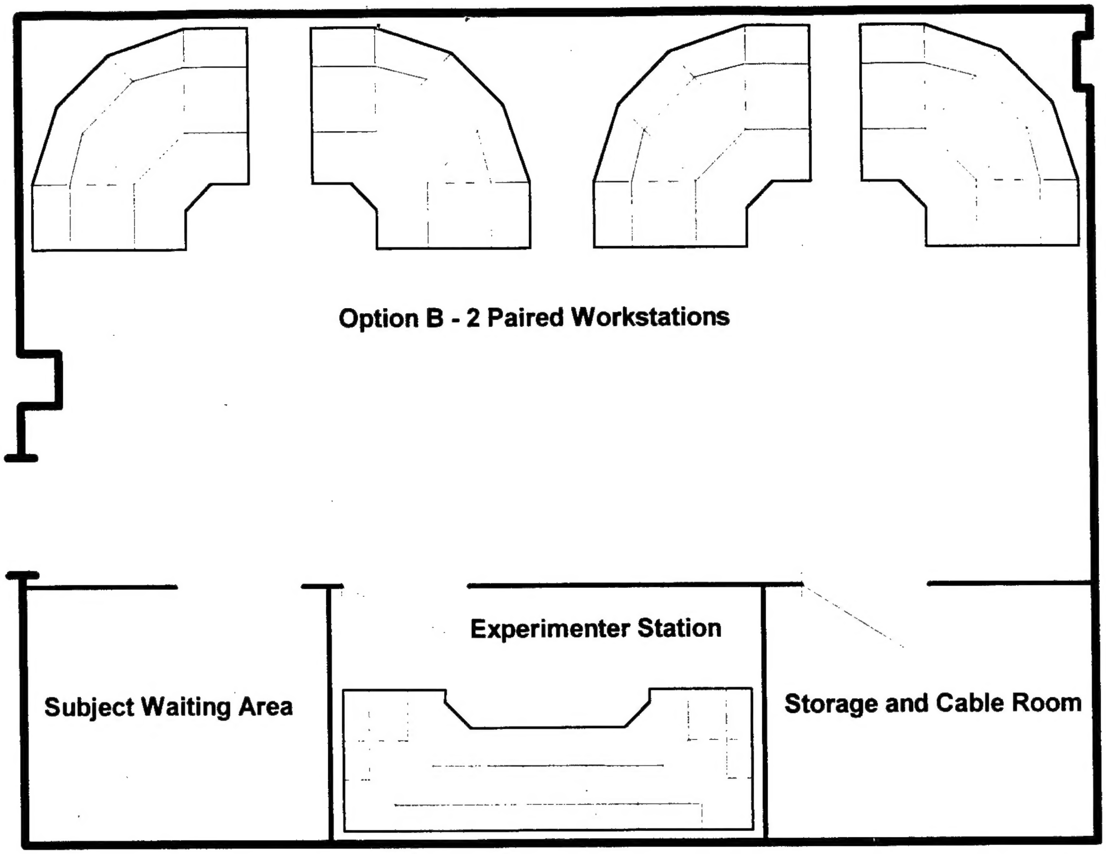


Figure 3. CERTT Floor Plan - Console Layout Option B *(drawn to scale).*

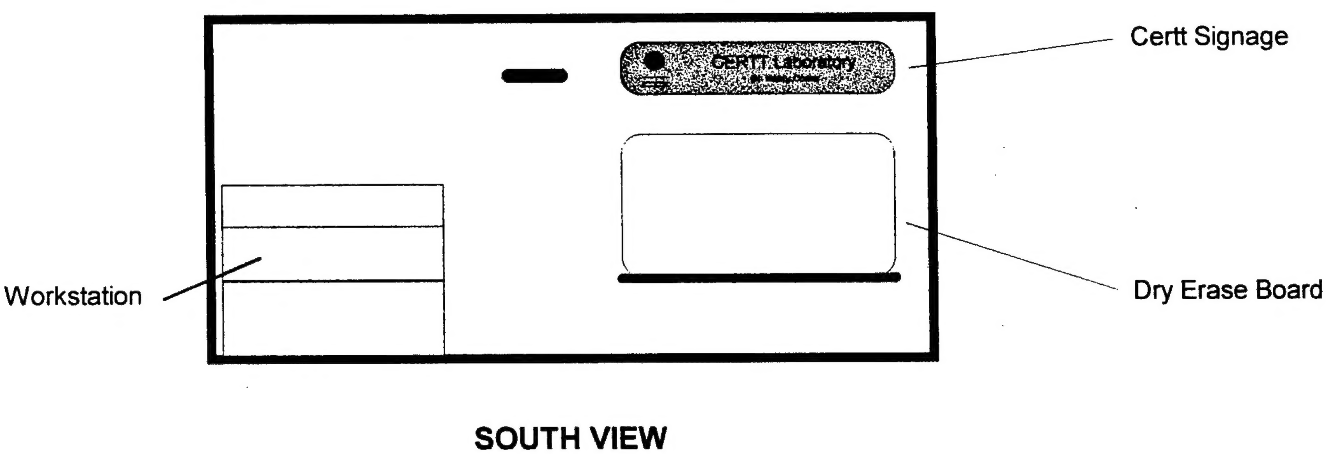
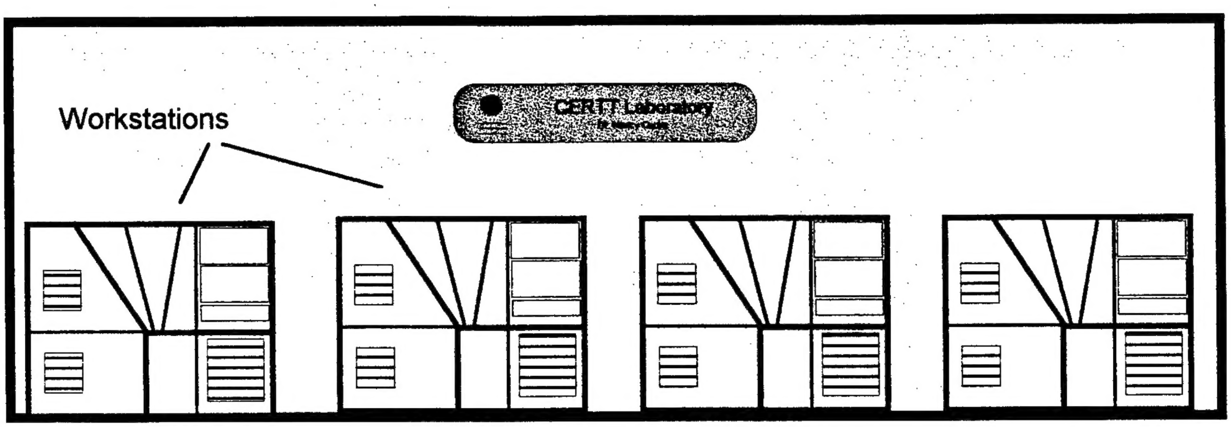
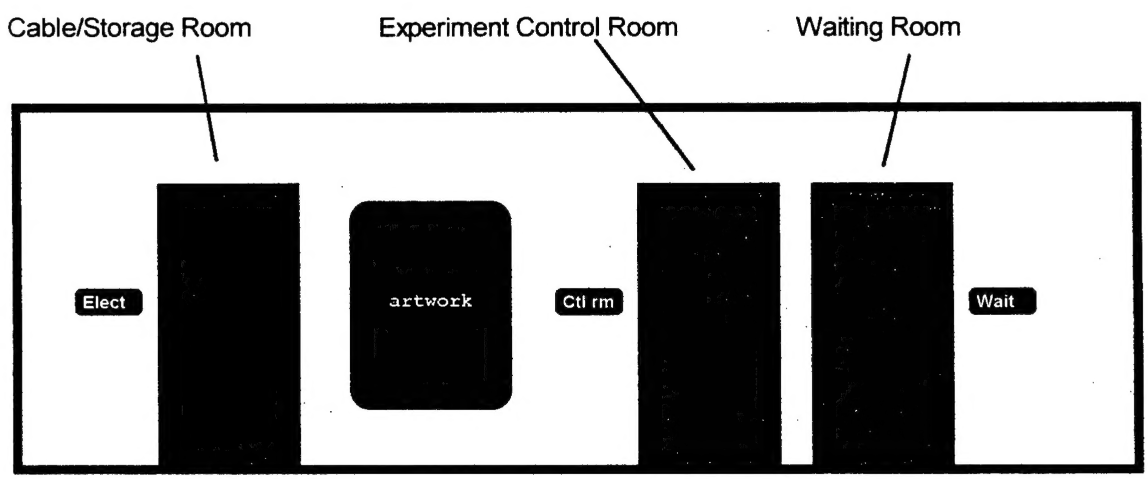


Figure 4. CERTT Laboratory South Wall View



EAST VIEW

Figure 5. CERTT Laboratory East Wall View



WEST VIEW

Figure 6. CERTT Laboratory West Wall View

III. Workstation Design

The CERTT Lab consists of four participant workstation and one experimenter workstation. Each of the participant workstations consists of two computers and monitors, a video monitor, a joystick, a keyboard and mouse, a headset and intercom, along with a variety of other lights, power switches, and indicators. These devices are configured in each of the three-sided, 90°, workstations as indicated in the following diagrams. The consoles are manufactured by Winsted Industries and are similar to those used in the video production industry and television studios. The primary computer is a NT-based system having a 17-inch monitor. The secondary computer is a rack mountable industrial computer produced by Cyber Research. This computer is used primarily for monitoring, tracking, and various secondary tasks, whereas the primary computer displays most of the main information for the synthetic task. The RGB video monitor, a rack-mount Sony unit, allows the presentation of video training or task materials. On the experimenter console the video monitor permits the experimenter to view each of the four participants via a Sony video camera mounted to the ceiling behind each of the four participants. The lab design allows the monitoring cameras to be easily moved. The joystick is a military aircraft styled unit and allows for realistic flight-related interactions with the system. Care has been taken in the design of the workstations, to simplify the functions available to the user and to disable any functions that are not necessary or desirable for the user to perform (e.g., turning off the main power.)

Careful planning went into the communication module of the workstations. The headsets and intercoms provide direct experimenter control of various communication pathways among team members. The experimenter specifies those paths that are viable. In addition, audio data will be recorded in sync with other data records (i.e., time-stamped) and will identify not only time of communication, but speaker's and listener's identities as well. The communication module also creates auditory isolation of team members when necessary.

One ASL head tracker will be included in the CERTT Lab. This allows for recording of the position of the team member's head at a finer level than can be obtained from video records. It was determined that for workstations so big, that an eye-tracker-level of resolution was not justified nor desirable because of the wide angle of view (90°) of the participant workstation. The four participant workstations and the experimenter station are connected locally using a 100BaseT local area network. Additionally, the system can be readily connected to the internet via the NMSU network

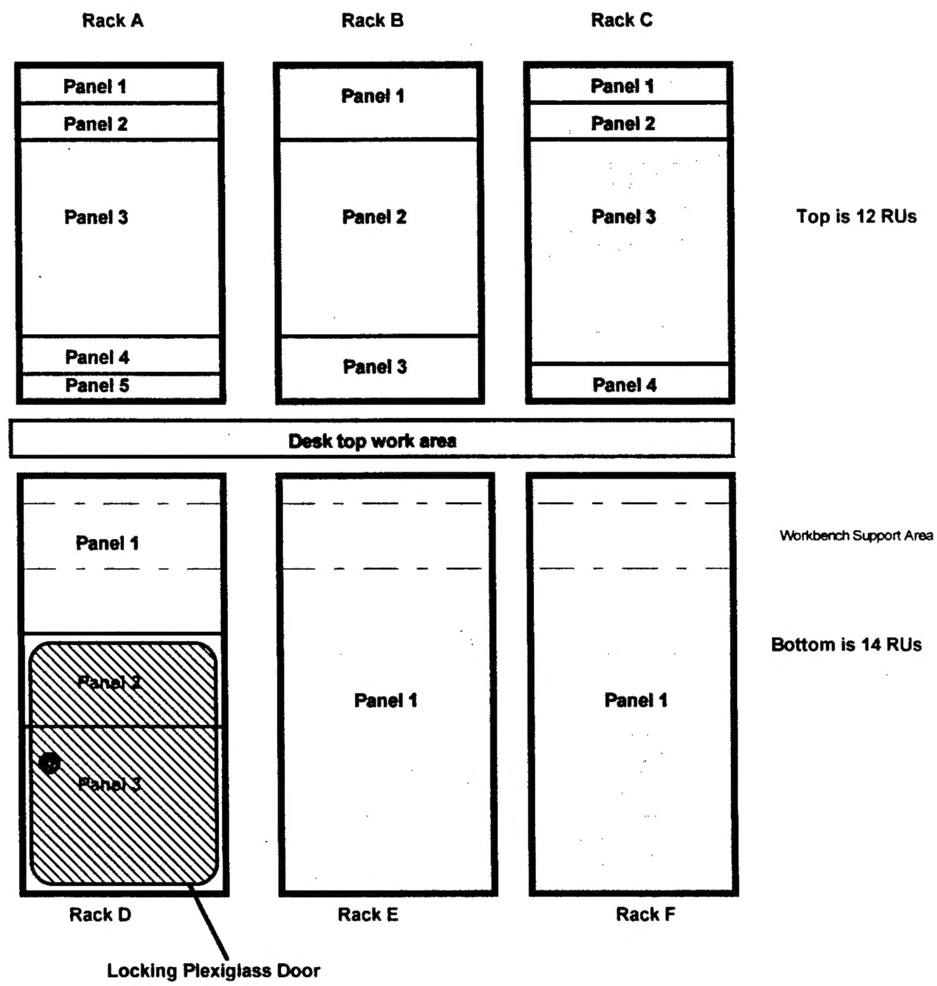


Figure 7. CERTT Workstation Console Layout

IV. Software Design

Software design for this project continues by Sandia Research Corporation at no additional cost to this project. The careful planning that went into the construction of the workstations described above has laid the ground-work to support a wide variety of synthetic task scenarios and software modules to support experimentation. These modules and their functions are described in Section A below. Software modifications will continue with further test and redesign iterations. The first pass at the synthetic task itself is outlined in Section B. This design too is continually fine-tuned with feedback from test-design iterations.

A. Software Modules & Functionality

1. Event logger
- records user input to system (keystrokes, mouse clicks, joystick information)
- records any dynamic (i.e., unplanned) events/messages presented to user
- timestamps system events and user events (in sync with video and audio data)
- experimenter control of level of abstraction of recorded events
- flexible summary format
- interfaces with software tools for event analyses

2. Training module
- capability of presenting different training materials to each individual
- incorporates testing procedures (see factual test module)
- allows some material to be referenced throughout task

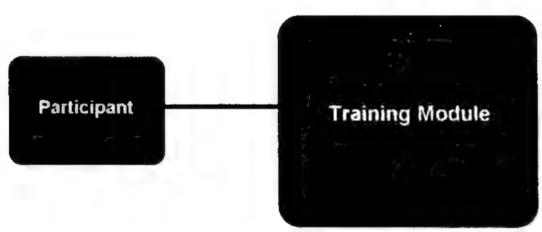


Figure 8. Software System Training Component

Knowledge elicitation modules

- Relatedness Ratings: This module takes a set of concepts and randomly presents pairs of these concepts, counterbalancing the order of the first item in the pair across subjects. Pairs are presented on the computer screen with a rating scale. Relatedness ratings are collected and summarized in a format that interfaces with analytic tools like Pathfinder
- Diagramming Module: This module allows the participant to create node-link diagrams in which nodes and links can be assigned verbal labels, links can be drawn in one or both directions, and links and nodes can be annotated according to strength. Data are summarized in a form compatible with analytic tools like Pathfinder.
- Factual Tests: This module randomly presents test questions or surveys, collects the responses, and in the case of close-ended questions, scores responses and is capable of providing immediate feedback when required. Data are recorded and summarized in format specified by experimenter.

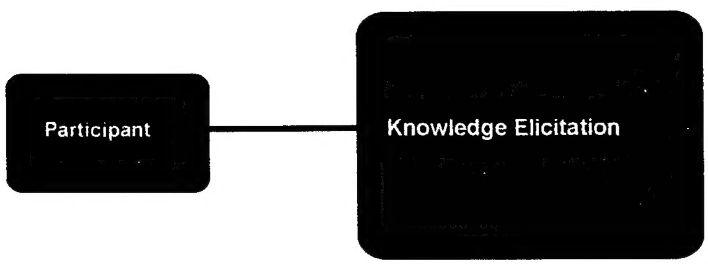


Figure 9. Software Knowledge Elicitation Component

3. **Task Modules**
   - Embedded Measures: Task can be interrupted to present queries; but in many cases these measures are collected as part of the task (e.g., task outcome, performance (time, accuracy), situation awareness).
   - Experimenter Annotations: Experimenter has capability of annotating aspects of team interactions occurring throughout the task. These data are summarized and time-stamped so that they are in sync with other records of task activities.
   - Experimenter Control: The task has parameters that can be controlled by experimenter (e.g., degree of complexity, coordination demands, degree of team interdependence, degree of ambiguity, time pressure, presence of conflict, severity of consequences, framing of problem, presence of dynamic events). The experimenter also has the ability to alter these parameters at the level of the individual console.
   - Task-Specific: Modules such as briefing, planning, navigation aspects of the task are designed in modules so that the task can maximally re-configurable (e.g., for other synthetic tasks such as air traffic control, flight crew missions).

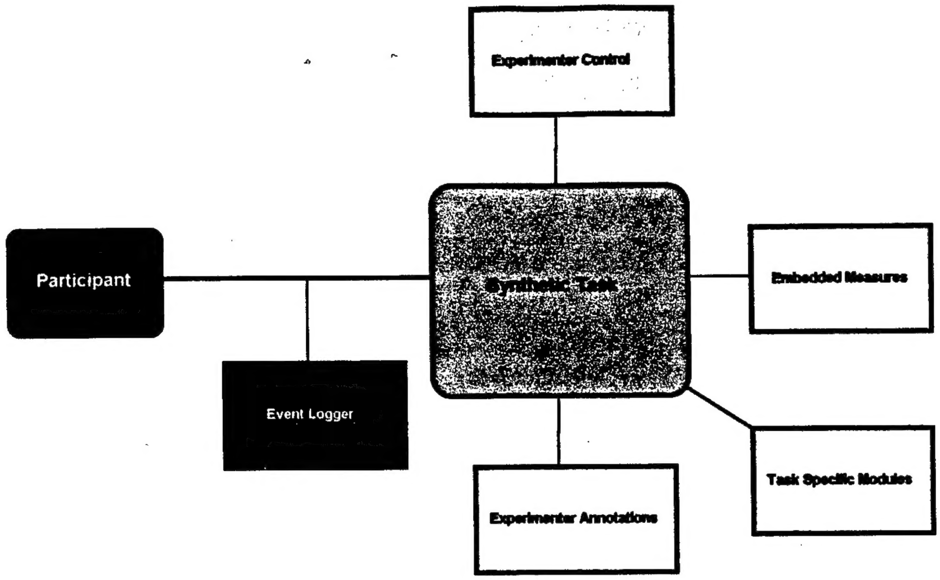


Figure 10. Software Synthetic Task and Event Logger

B. The UAV Synthetic Task

The needs analysis indicated that the synthetic task should be cognitively complex. In other words, it should require cognitive team activities such as team decision making, team situation awareness, knowledge sharing, planning, and communication. It was also important that it have features associated with team interaction such as distributed expertise, team member interdependence, dynamic interplay between team members, and the sharing of scarce resources. Finally, it was also critical that the task be understandable and be engaging for college undergraduates.

With these objectives in mind a UAV scenario to serve as the backbone of the initial synthetic task was scripted. An outline of the scenario is presented below.

Initial UAV Scenario

<u>Background for all team members:</u>

> *There have been intelligence reports that the cite of a small college in Western Australia has now become a center for nuclear weapons which are to be sold to Iraq. Your mission is to bring back aerial photos of this cite.*

During the scenario events are subject to change. These events include weather conditions, aircraft malfunctions, payload malfunctions, and enemy activities.

Roles of three team members:

1) ***AVO (Air Vehicle Operator):***
Responsibility: Is responsible for operating an unmanned air vehicle between Phoenix, AZ and Western Australia.
Individual Goals: Take-off, landing, and safe operations of UAV. AVO is also responsible for detecting any equipment malfunctions, diagnosing them, and taking appropriate action.
Training: AVO receives individual training in using a flight simulator program.
Information Available: Lists of common malfunctions, diagnoses, and recommended actions, computer also displays indications of malfunctions
Actions Available: Basic flight operations, maintenance actions (checks, repairs)

2) ***Mission Commander*:**
Responsibility: Responsible for overseeing mission, route planning, making any necessary changes in mission.
Individual Goals: Navigation and route planning. Accomplish mission while minimizing flight time and ensuring safety of the equipment and other team members. Facilitate team coordination.
Training: Will receive training in team coordination (planning, communication). In addition will receive training in navigation (map reading, GPS use).
Information Available: Details of mission and background, including a map of various routes and details associated with each (i.e., terrain, enemies, mileage, etc.). Will also get periodic weather reports via computer and GPS information.
Actions Available: Route information can be selected which is then sent to AVO

3) ***Payload Operator:***
Responsibility: Responsible for taking pictures remotely of designated cite, also responsible for identifying potential threats to aircraft from enemies.
Individual Goals: Identify target, direct camera, take picture, zoom as needed, predict potential threats and communicate them to the Mission Commander.
Training: receives training in the use of the camera and identifying and predicting enemy operations.
Information Available: Cues that help identify designated cite (e.g., photo of surrounding area), intelligence information about potential covert enemy operations (both on paper and during task via computer)
Actions Available: direct camera, zoom, take pictures, query an intelligence database

V. Conclusion

The CERTT Laboratory offers a flexible configuration of hardware and software to support the development of a variety of synthetic tasks. The lab is particularly suited to the implementation of synthetic team tasks requiring information sharing, communication and coordination among two to four team members. Most importantly, the CERTT Lab provides a *research environment* for the study of team cognition. Hardware and software permit flexible data recording and summarization from a variety of sources including video, audio, computer, and head tracking equipment. In addition, the experimenter has a variety of software options for experimental control. This experimental control and data recording flexibility in conjunction with the synthetic team task environment make the CERTT Laboratory a unique and valuable research tool for the study of team cognition.